Effects of Vehicle Weight and True Versus Indicated Airspeed on BVI Noise During Steady Descending Flight

Presented by:

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Motivation

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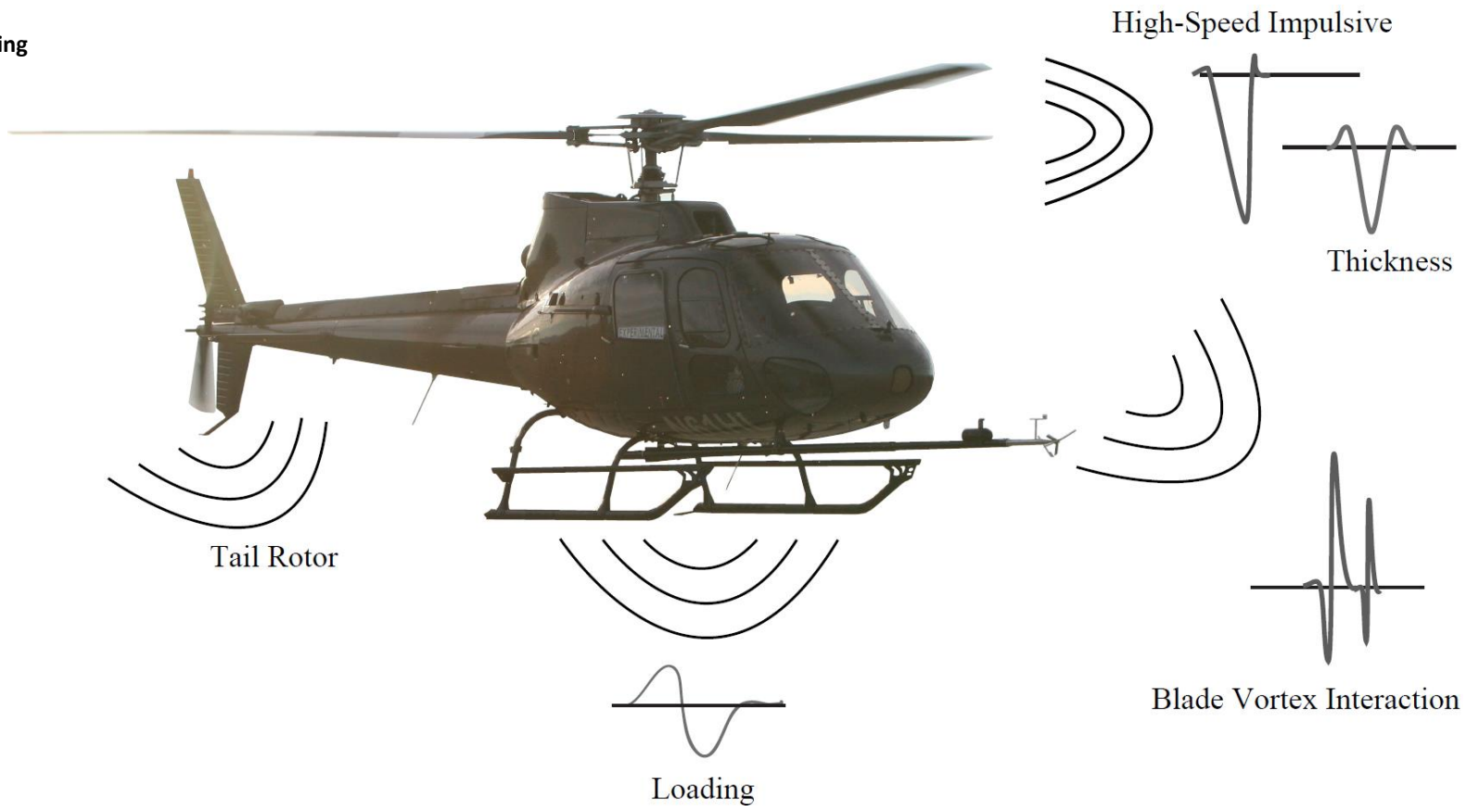
Stephenson & Greenwood



Motivation

Aerodynamics Affecting BVI Noise

- Inflow
- Blade Loading
- Advance Ratio

Flight Test Uncertainties

- Inconsistent Vehicle Flight Path
- Inconsistent Vehicle Velocity
- Atmospheric Effects (Wind, Temperature, Etc.)
- Blade-Blade Variations
- Variable Weight (Fuel burn)

Schmitz, F. H., Boxwell, D. A., Lewy, S., and Dahan, C., "In-Flight Far-Field Measurement of Helicopter Impulsive Noise," *American Helicopter Society 32nd Annual Forum*, 1976.

Lowson,M. V., "Focusing on Helicopter BVI Noise," *Journal of Sound and Vibration*, Vol. 190, (3), 1996, pp. 477–494.

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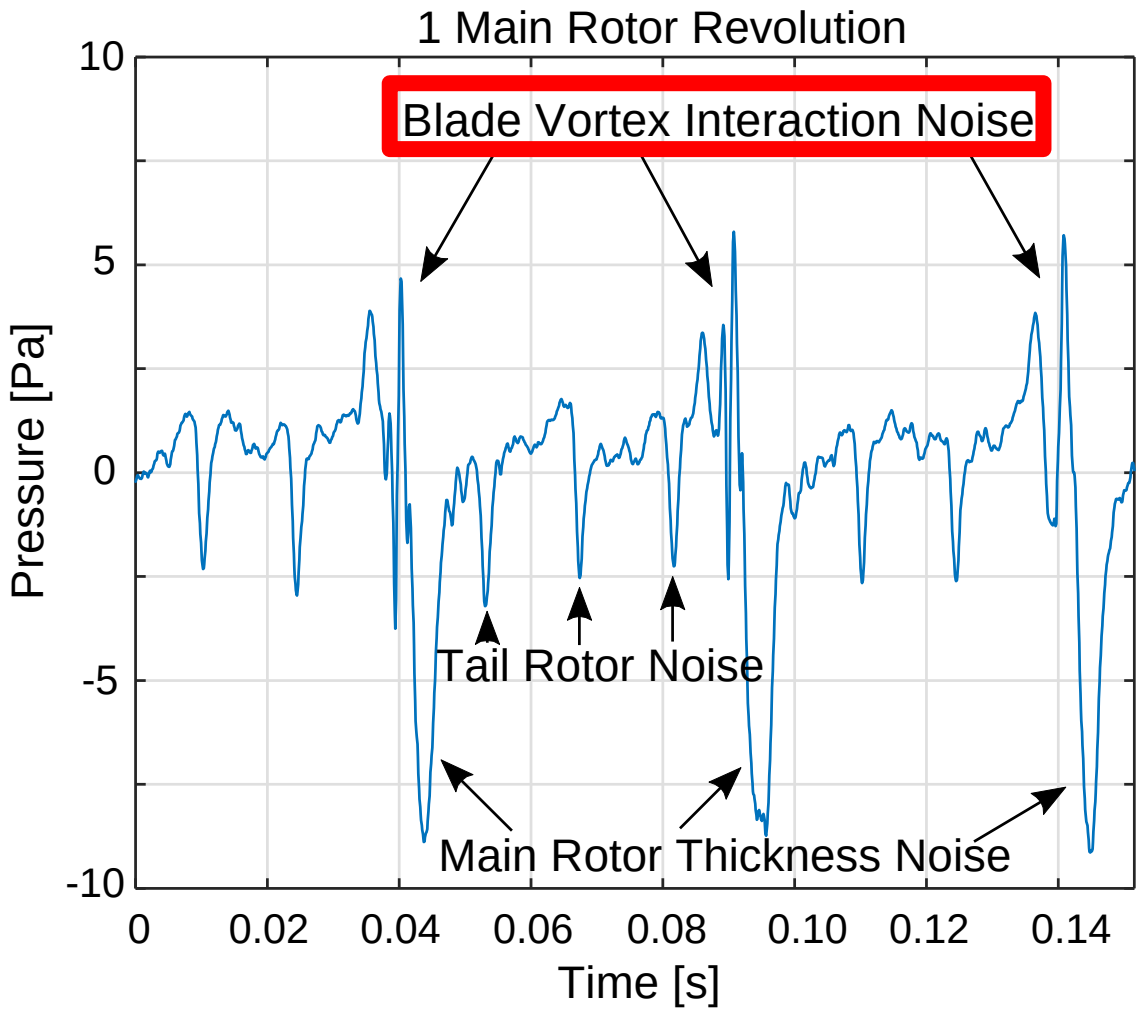

Analysis Technique

Wavelet Transform

$$\tilde{p}(l,t) = \frac{1}{\sqrt{l}} \int_{-\infty}^{\infty} p(t')\ \psi_w^*\left(\frac{t'-t}{l}\right) dt'$$

Morlet Wavelet

$$\hat{\psi}_M(l\ \omega, \omega_\psi) = \sqrt{2\pi l\ \frac{f_s}{N}}\ \pi^{-1/4}\ H(\omega)\ e^{-(l\omega-\omega_\psi)^2/2}$$

Wavelet Energy

$$E(f,t) = \frac{1}{C_\psi}\ \frac{|\tilde{p}(f,t)|^2}{l^2}$$

Inverse Wavelet Transform

$$p(t') = \frac{1}{C_\psi} \int_{-\infty}^{\infty} \int_{l} \frac{1}{\sqrt{l'}}\ \tilde{p}(l',t)\ \psi_w\left(\frac{t'-t}{l'}\right) \frac{dl'\ dt}{l'^2}$$

Torrence, C. and Compo, G. P., "A Practical Guide to Wavelet Analysis," *Bulletin of the American Meteorological Society*, Vol. 79, (1), 1998, pp. 61–78.
Farge, M., "Wavelet Transforms and their Applications to Turbulence," *Annual Review of Fluid Mechanics*, Vol. 24, 1998, pp. 395–457.

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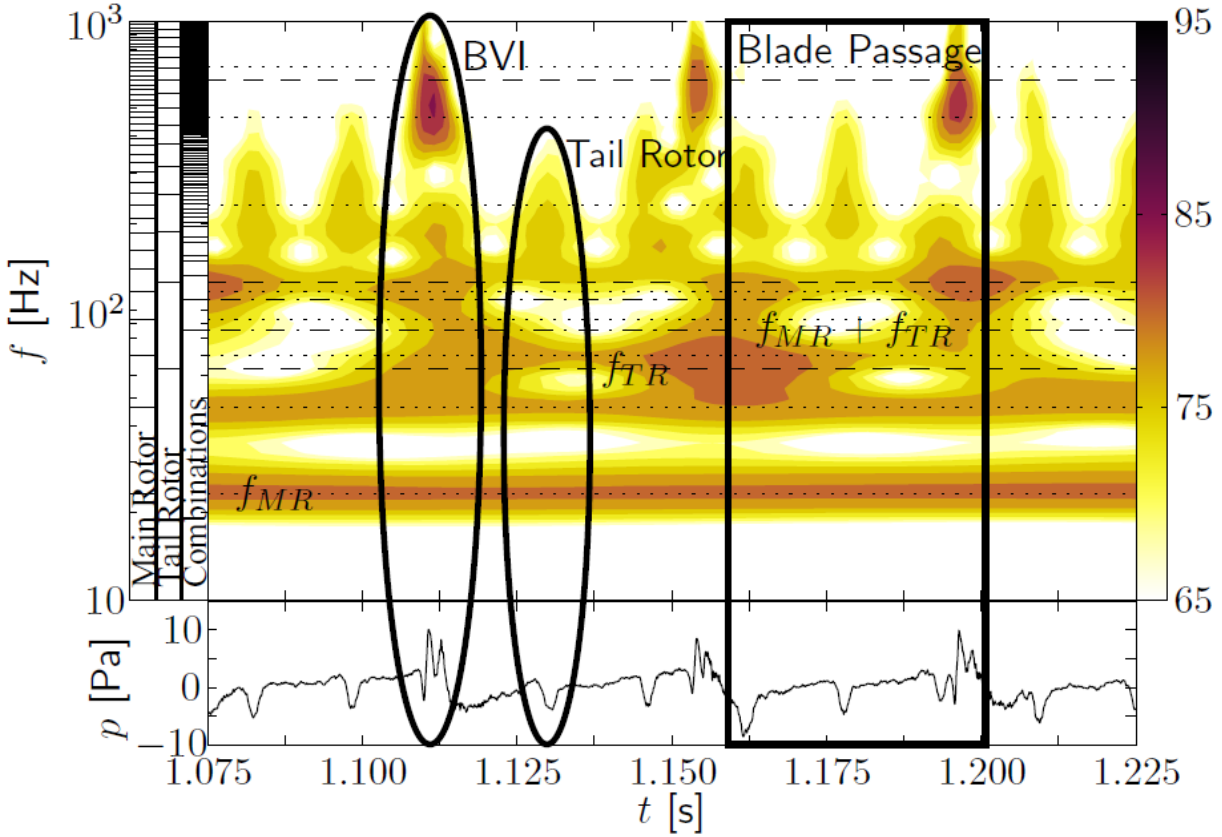
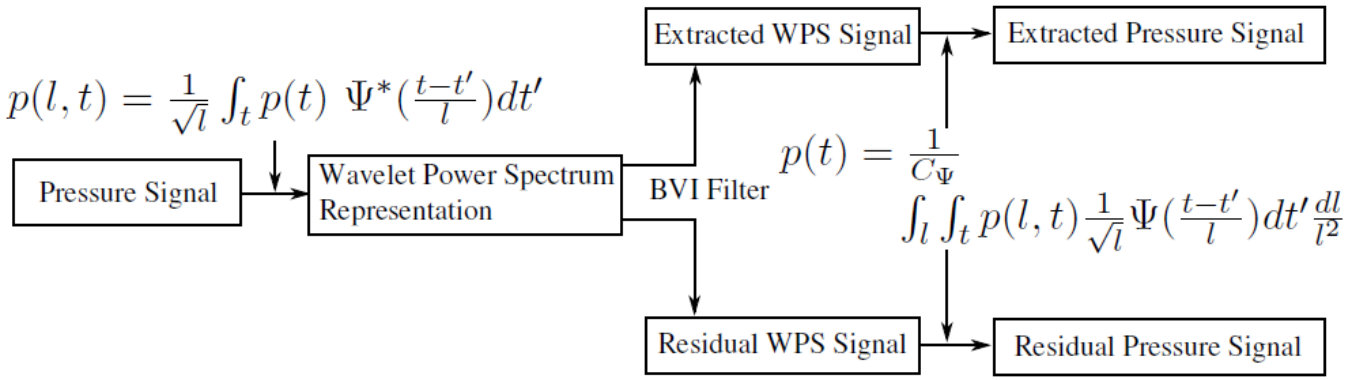


Martin, R. M. and Hardin, J. C., "Spectral Characteristics of Rotor Blade/Vortex Interaction Noise," *Journal of Aircraft*, Vol. 25, (1), 1988, pp. 62–68.
Stephenson, J. H., *Extraction of Blade Vortex Interactions from Helicopter Transient Maneuvering Noise*, Ph.D. thesis, University of Texas at Austin, 2014.

BVI Filter

$$\tilde{p}(f_j, t_i) = \begin{cases} \tilde{p}(f_j, t_i) & \text{if } f_j > f_{cut} \text{ and} \\ & E(f_j, t_i) > E(f_{MR}, t_i) - A_{cut} \\ 0 & \text{otherwise} \end{cases}$$



Davis, W., Pezeshki, C., and Mosher, M., "Extracting and Characterizing Blade–Vortex Interaction Noise with Wavelets," *Journal of the American Helicopter Society*, Vol. 42, (3), 1997, pp. 264–271.

Stephenson, J. H., Tinney, C. E., Greenwood, E., and Watts, M. E., "Extracting Blade Vortex Interactions using Continuous Wavelet Transforms," *Journal of Sound and Vibration*, Vol. 333, (21), 2014, pp. 5324–5339.

Experiment Description

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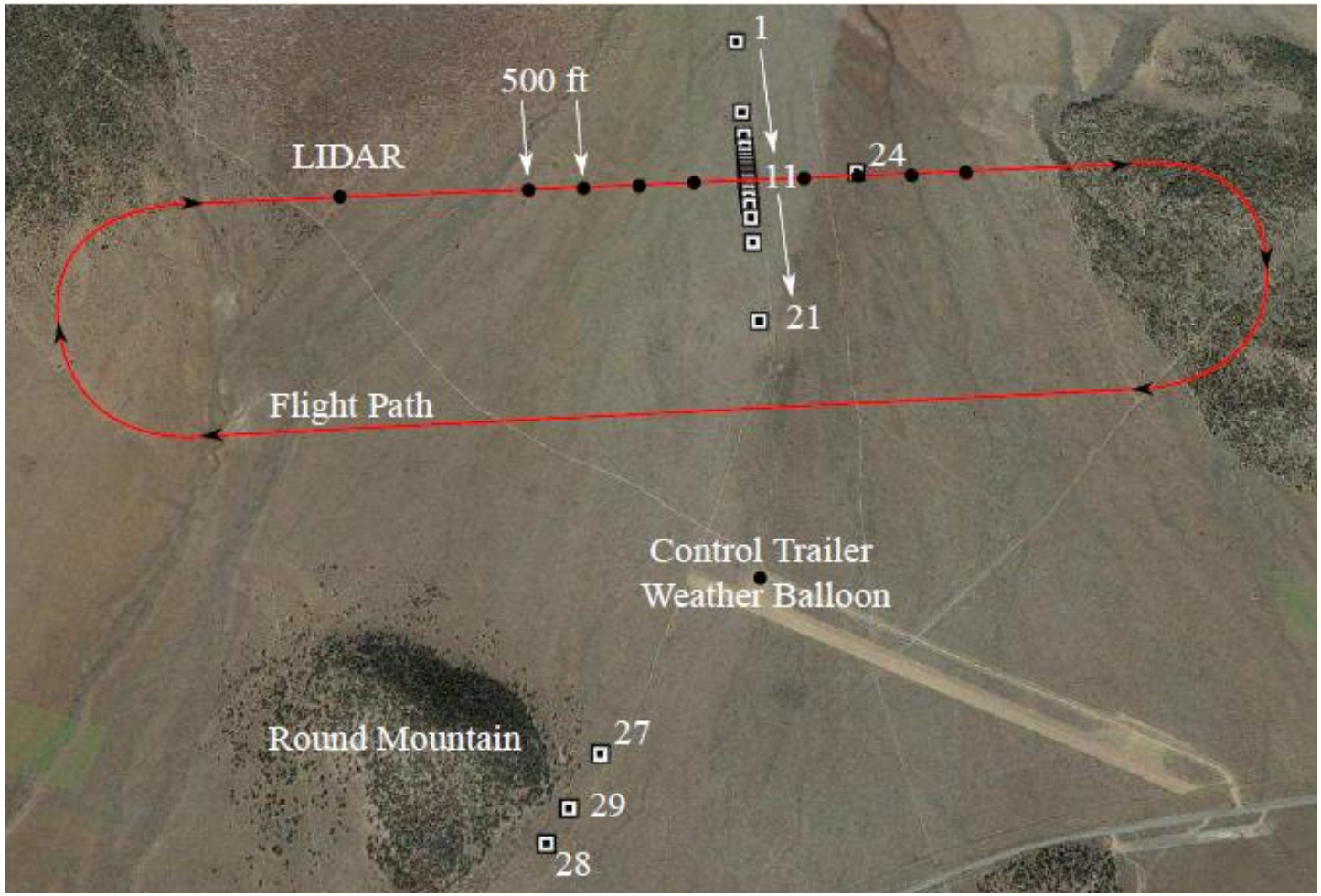

Experiment Description

- (28) Wireless Acoustic Microphone Systems
  - ½" B&K 4189 – 25 kHz sampling
  - 15" Diameter ground board
  - GPS Receiver

- Weather Systems
  - Tethered Weather Balloon
    - Weather Sonde (200')
    - (up to 4) Temperature, Humidity, Pressure Sensors (~50')
  - ZephIR 300 LIDAR System
    - Wind velocity at 12 altitudes up to 1000'
  - (5) Ground Weather Stations
    - Located near Mics 1,11,21,24,27

Vehicle Characteristics

	MR	TR	
Number of Blades	3	2	
Radius (R)	10.69	1.86	[m]
Blade Pass Frequency (f)	19.5	104	[Hz]

- Aircraft Navigation and Tracking System (ANTS) (20 Hz sampling)
  - GPS Receiver
  - Inertial Navigation Data
- Air-Data Boom (5 Hz)
  - Outside Air Temperature
  - Static and Dynamic Pressures
  - Wind Velocities

Flight Conditions

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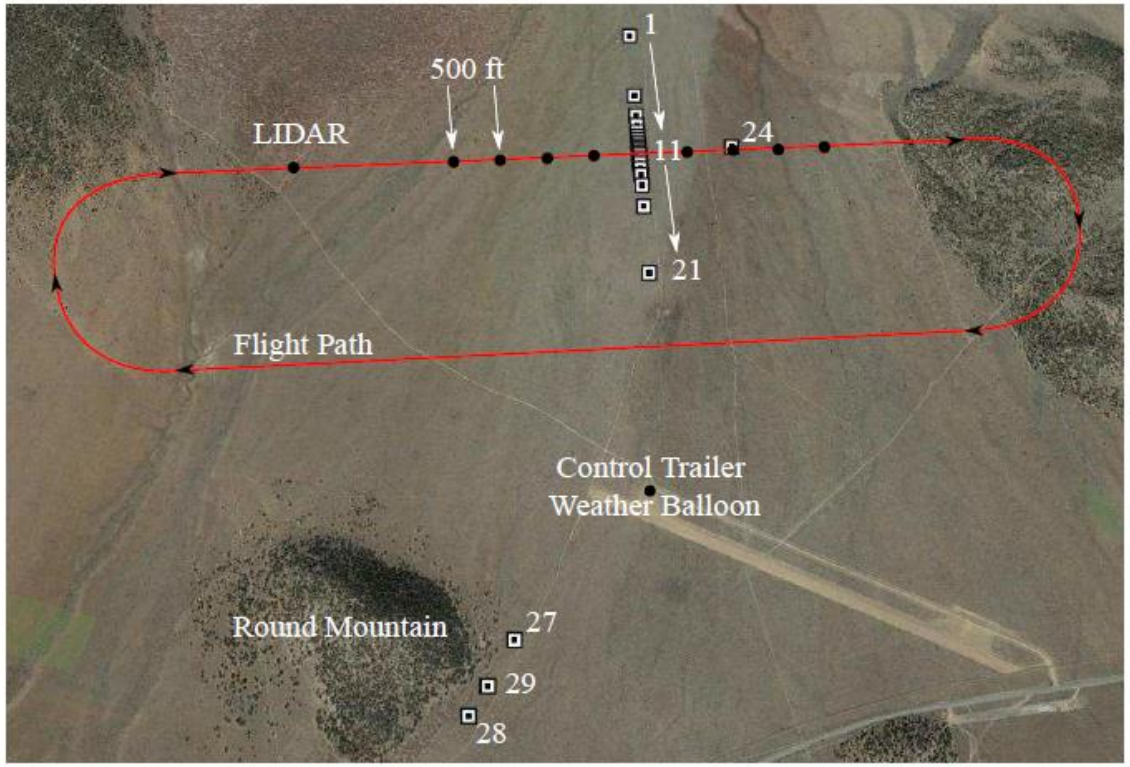

6° Descent Condition

	KIAS	KTAS	Nom. Takeoff Wgt 4400	3915 [lb]
80 KIAS	80	87 (Typ)	11	13
80 KTAS	73 (Typ)	80	12	13

Results

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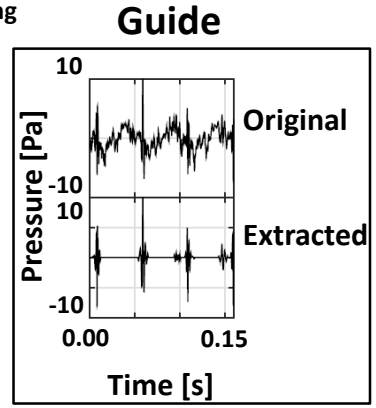

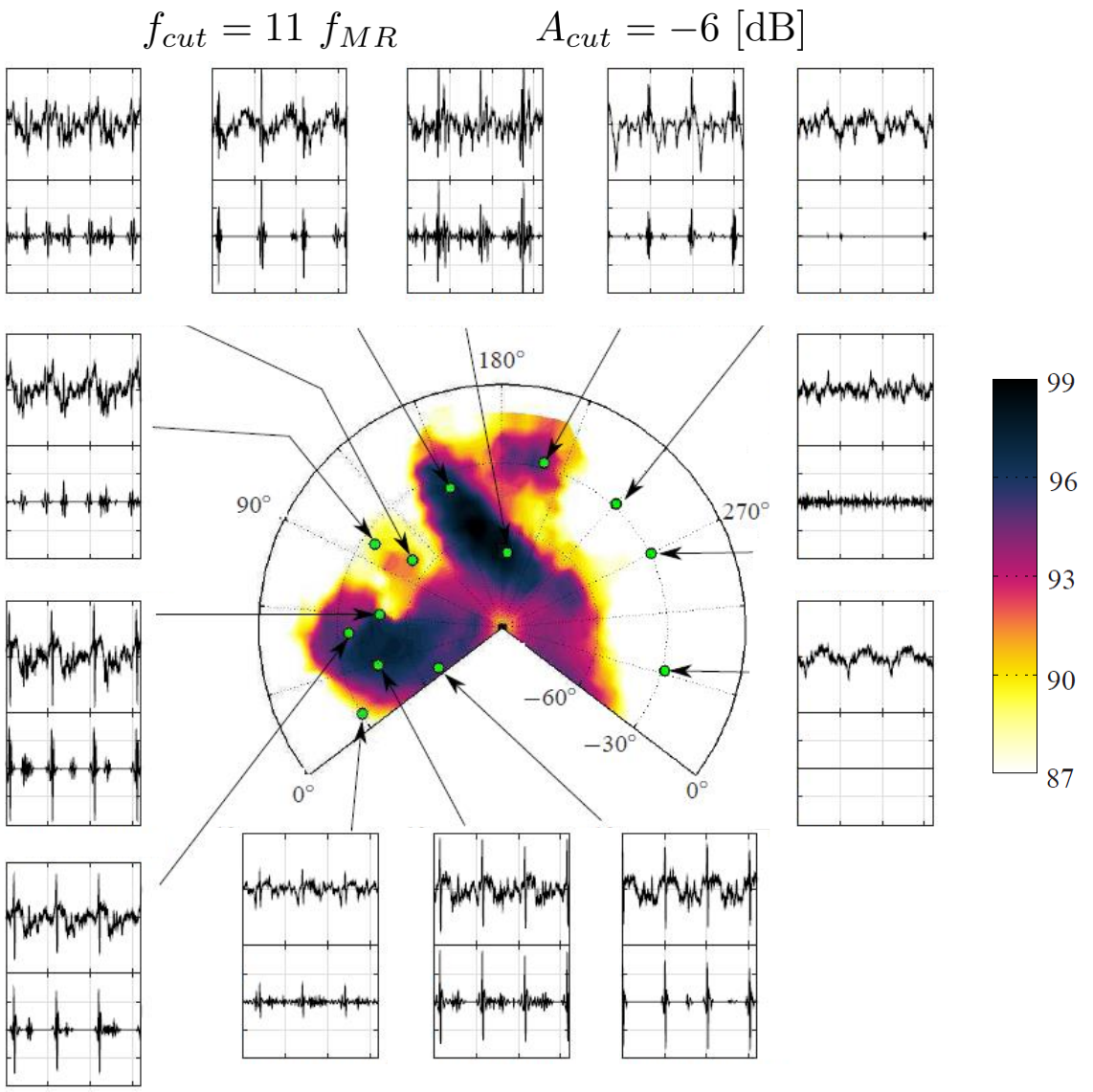

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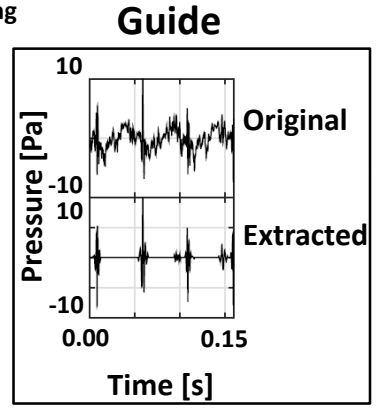
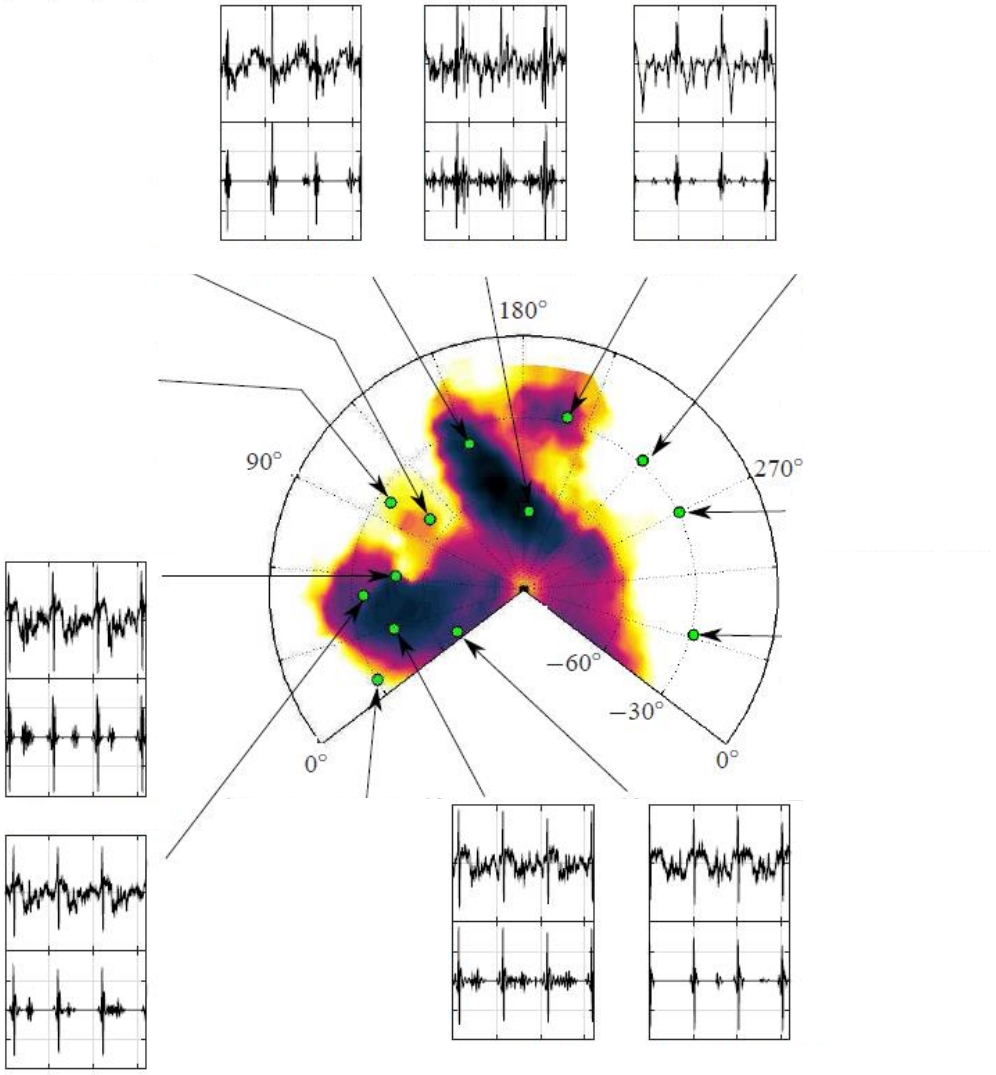


$f_{cut} = 11\ f_{MR}$ $A_{cut} = -6$ [dB]



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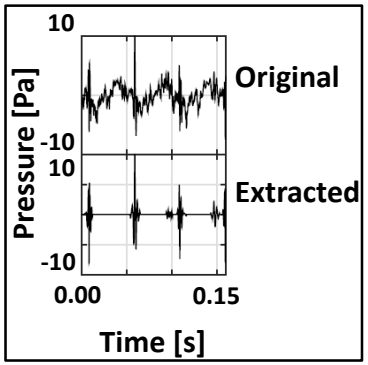

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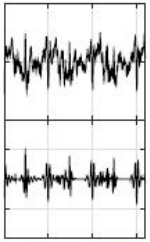

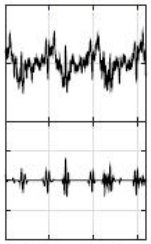

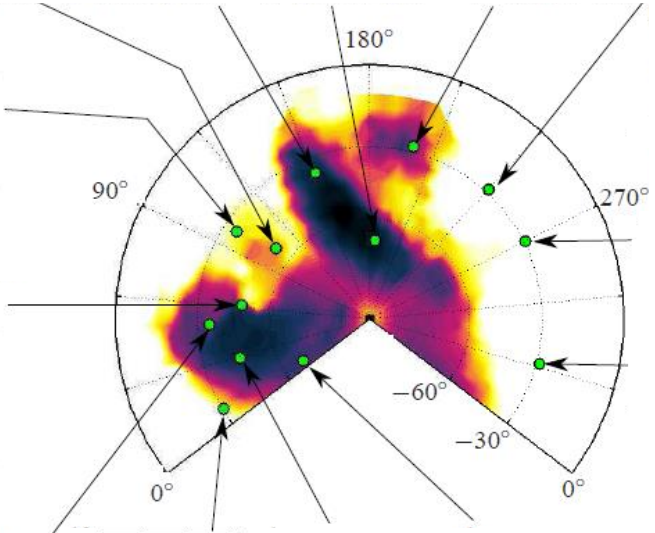

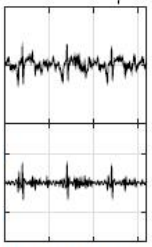

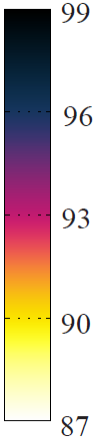

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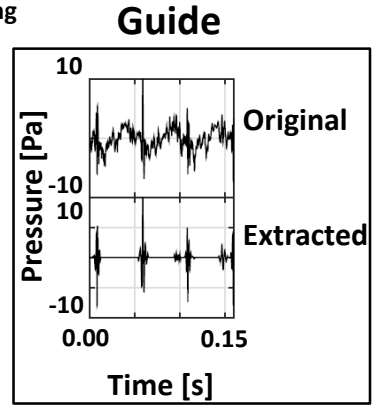

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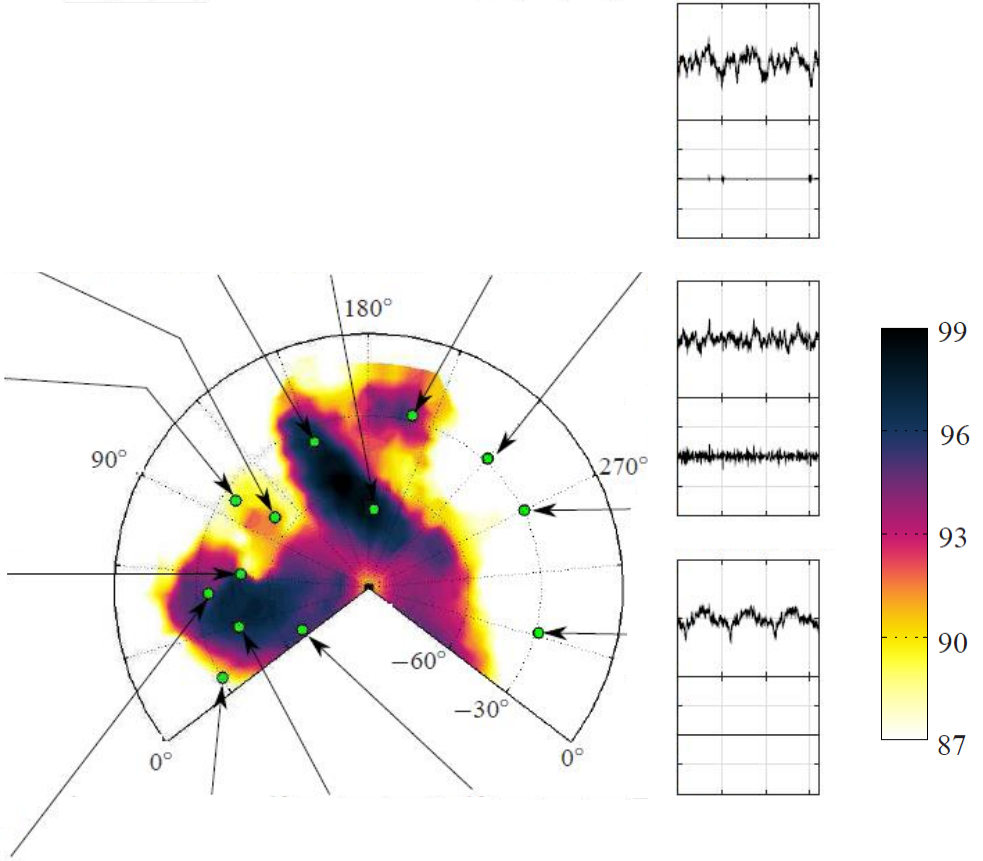

BVI Extraction VS BVISPL

Effects of Vehicle Weight and True Versus Indicated Airspeed on BVI Noise During Steady Descending Flight

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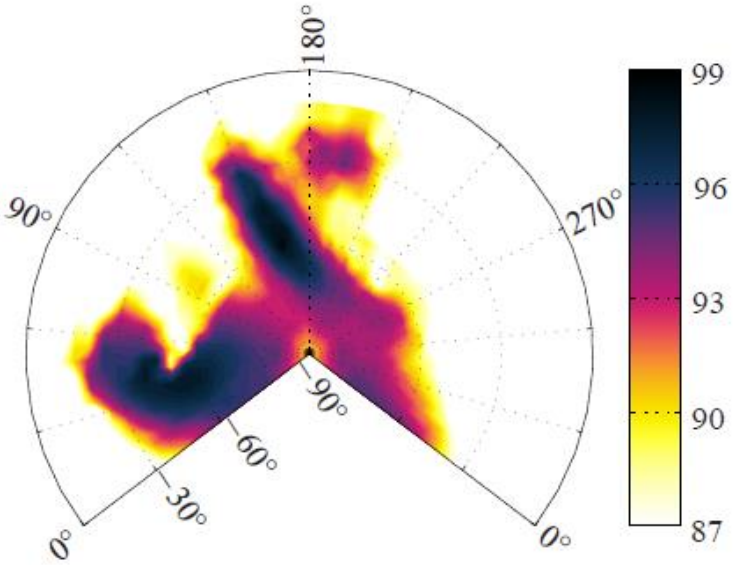
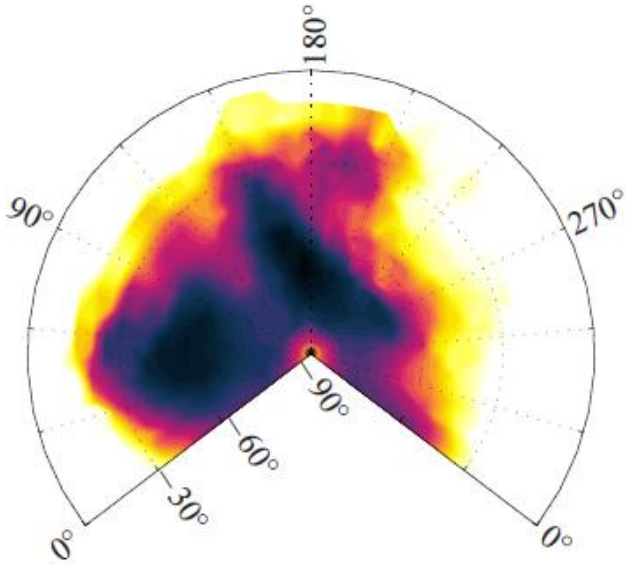
BVI Extraction [dB]



BVISPL [dB]



$$f_{cut} = 11\ f_{MR}$$

Average BVI

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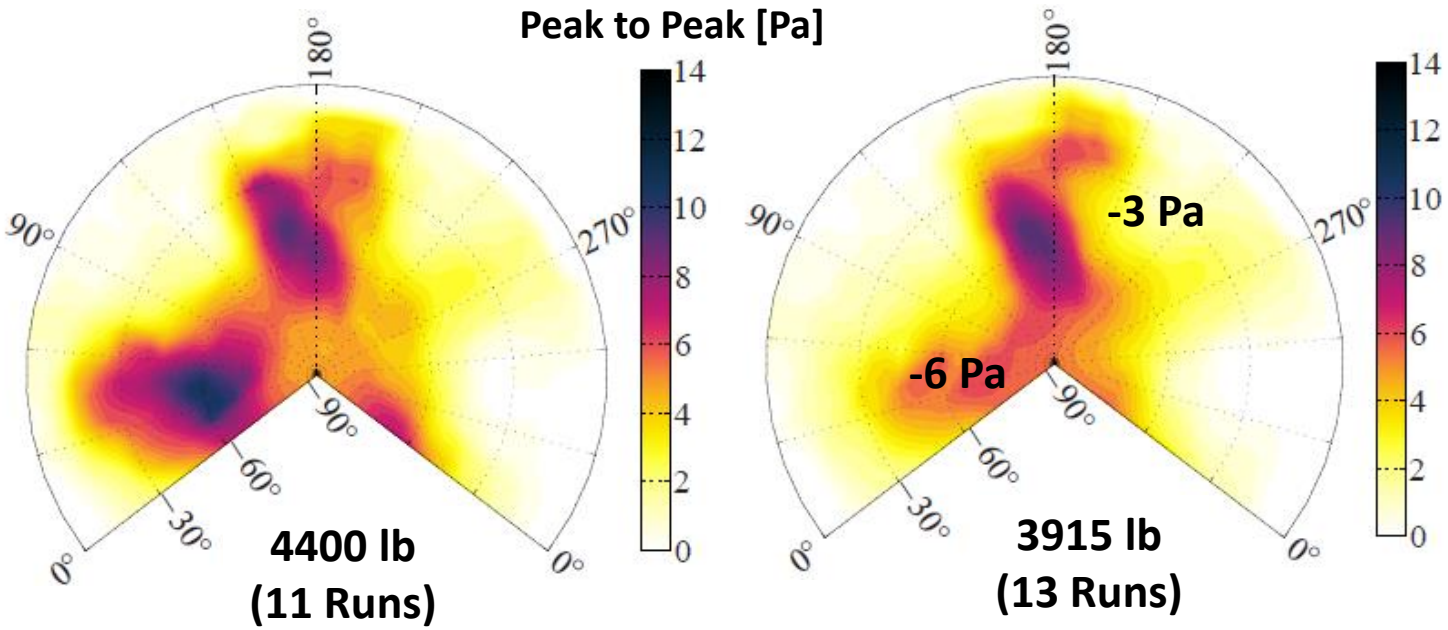
80 KIAS



$$\Delta W_{nom} = 11\% \rightarrow -1.5\ Pa \approx 1.0\ dB$$

$$\Delta W_{max} = 17\% \rightarrow -2.4\ Pa \approx 1.3\ dB$$

$$\alpha_{TPP} = -\frac{D}{W} - \gamma ?$$

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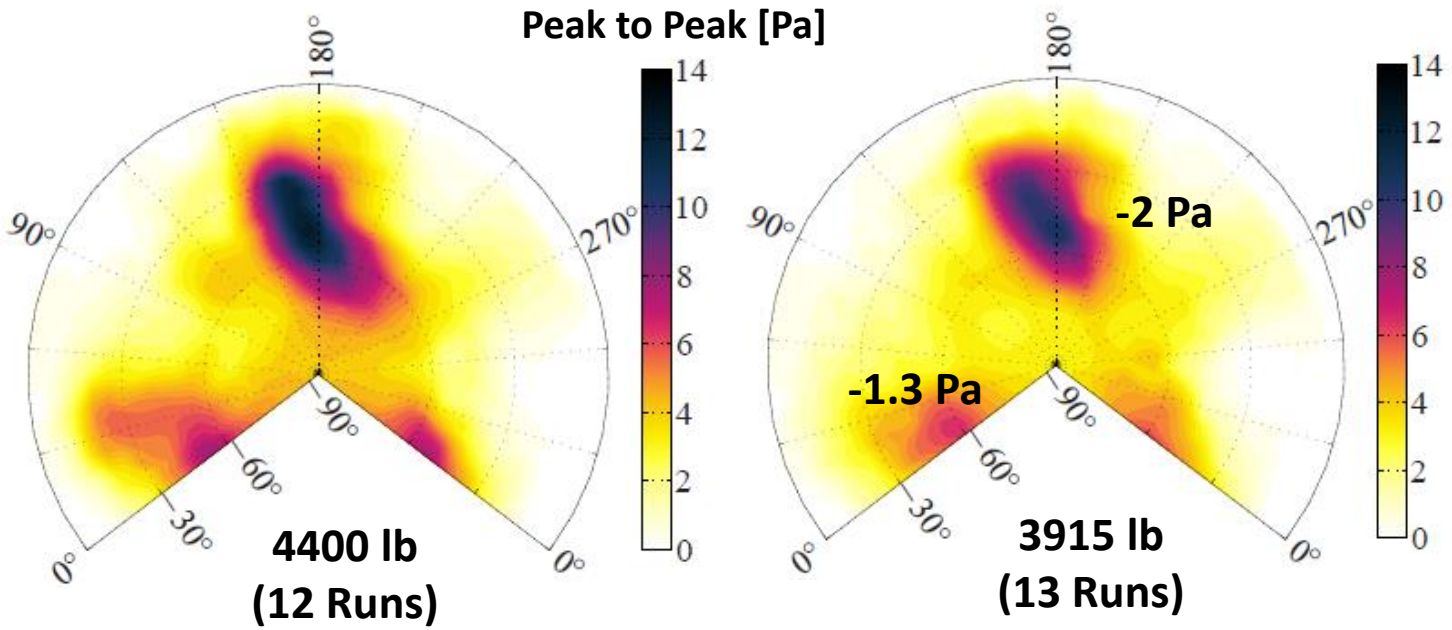
80 KTAS (~73 KIAS)



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BVI Standard Deviation

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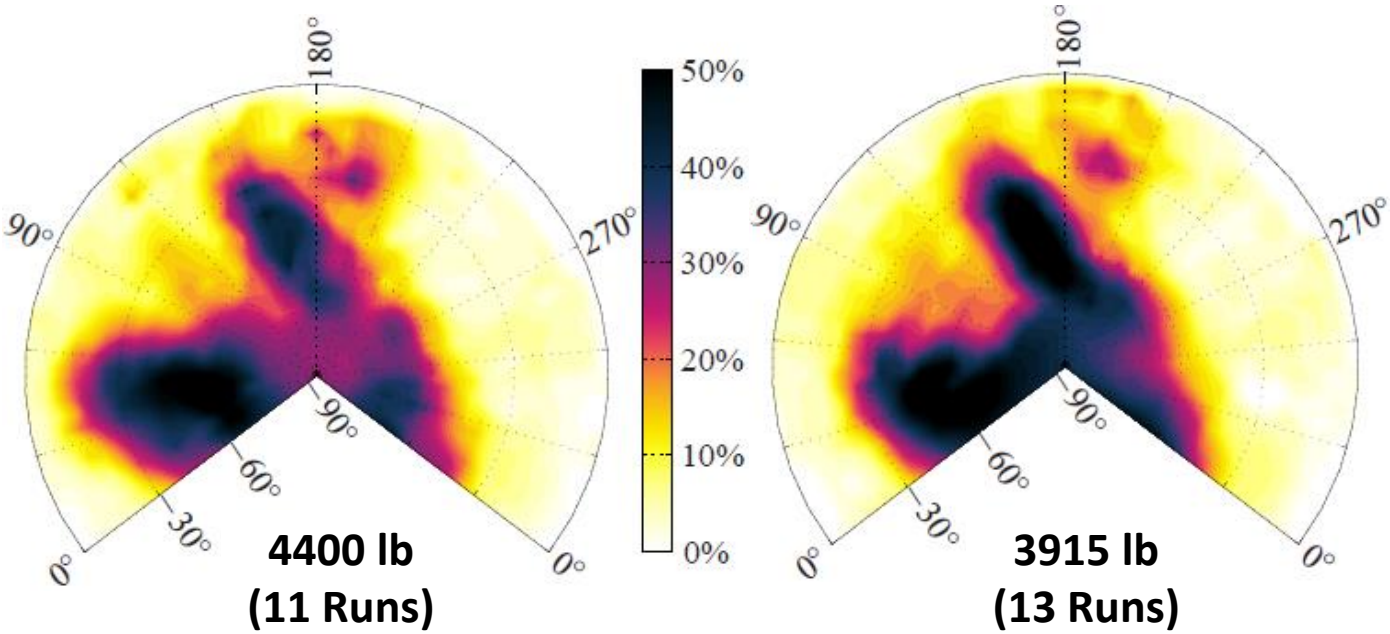
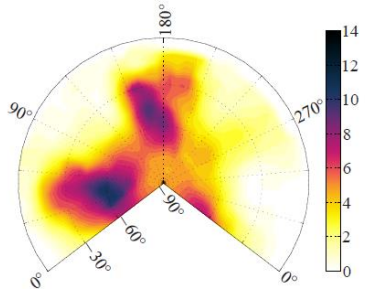
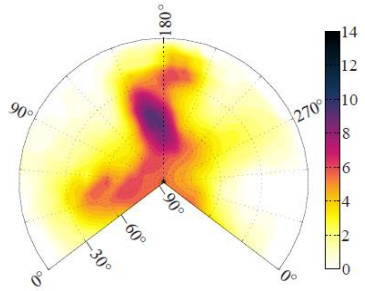


4400 lb (11 Runs)

3915 lb (13 Runs)





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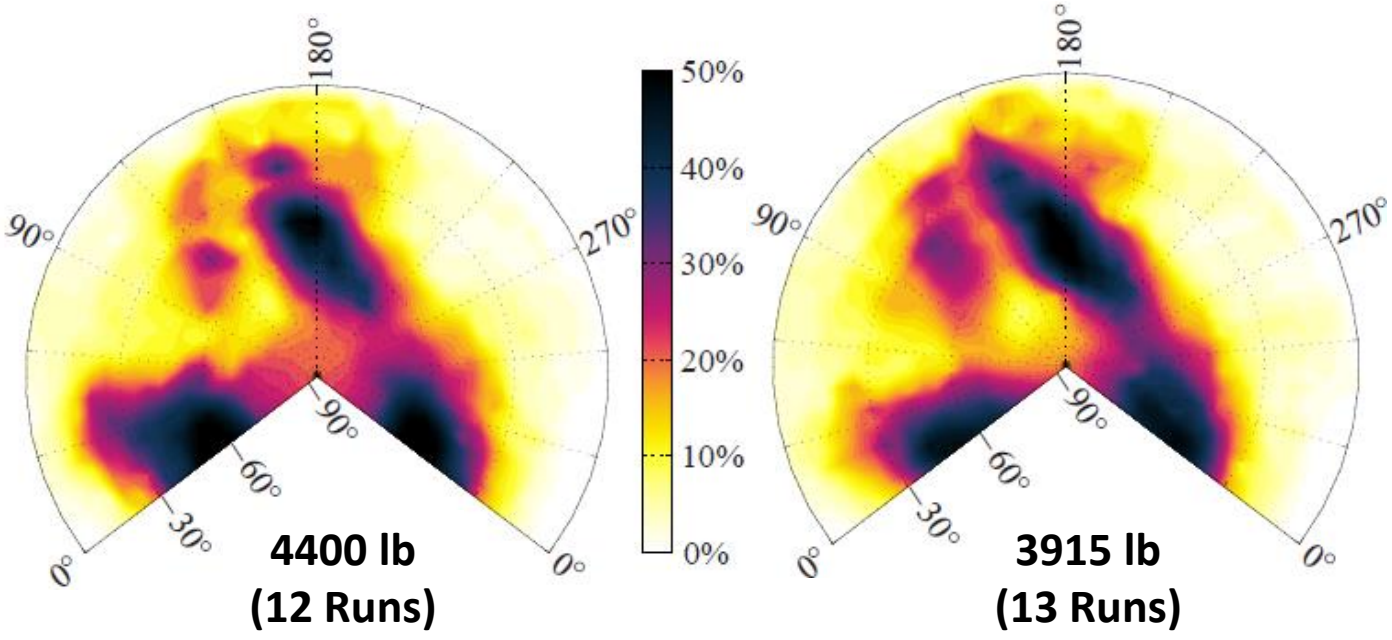
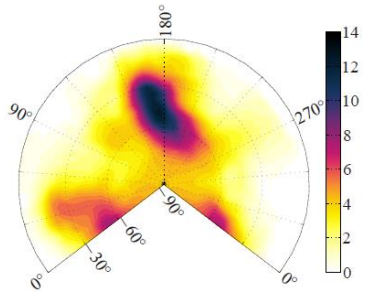
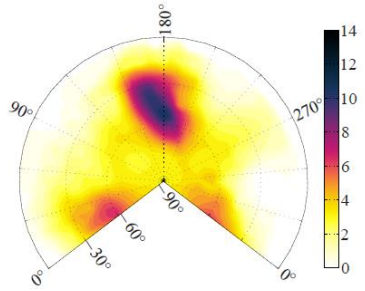


4400 lb (12 Runs)

3915 lb (13 Runs)





Conclusions

- BVI noise can be strongly affected by weight
  - Vortex Strength + Tip-Path Plane?

- BVI noise highly variable
  - Up to 50% of normalized standard deviation
  - Can be used to identify secondary BVI events

Questions?

Acknowledgements

- Mike Watts
- David Conner
- Keith Scudder
- Andrew McCrae
- Nikolas Zawodny
- Aris Helicopters

Flight Path and Speed Consistancy

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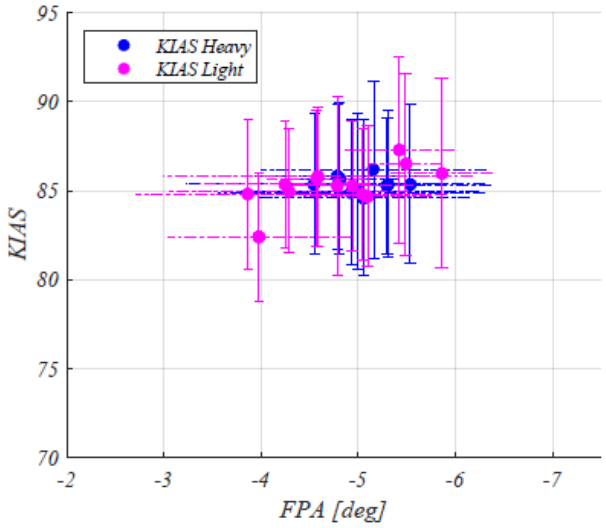

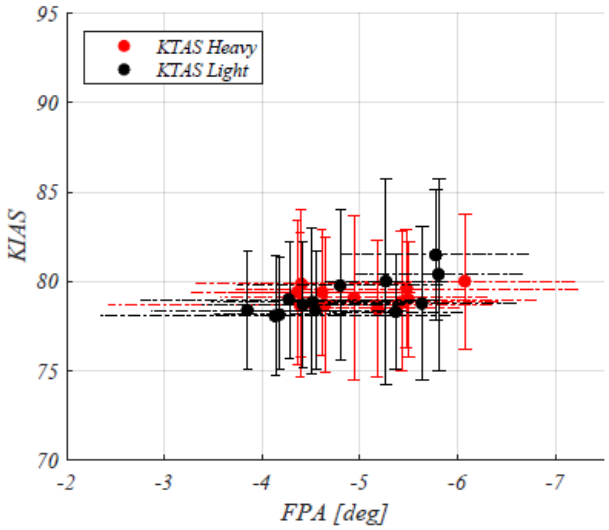

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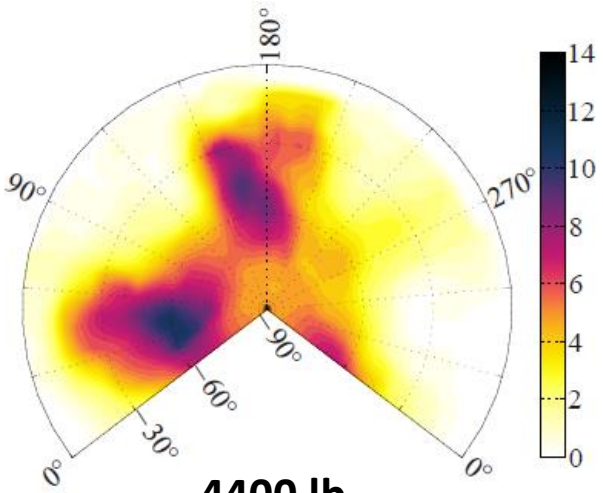

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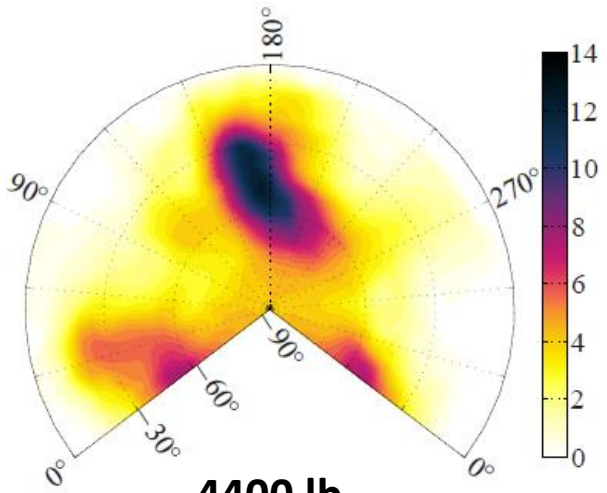

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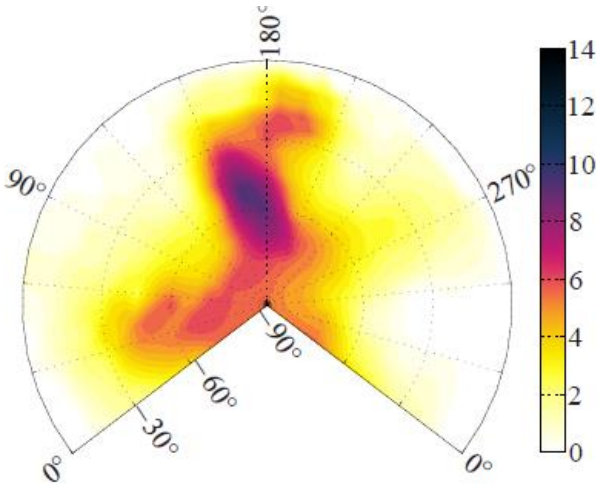

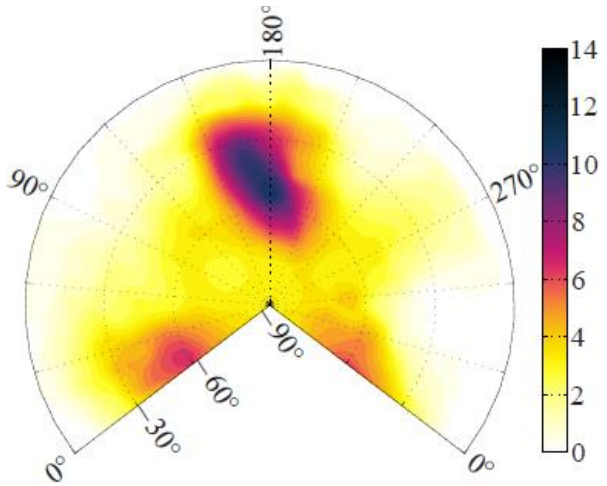

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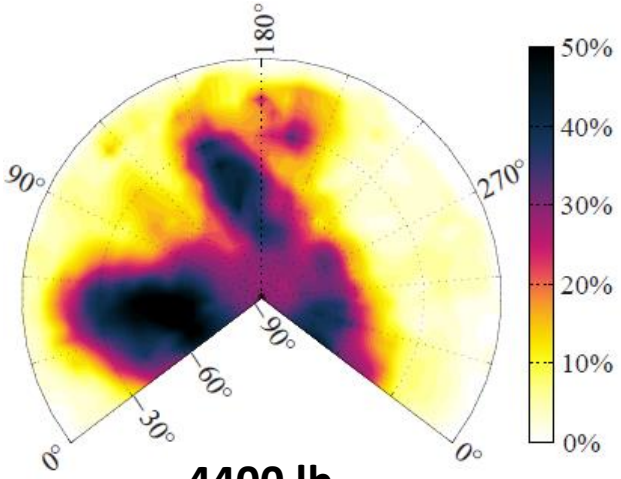

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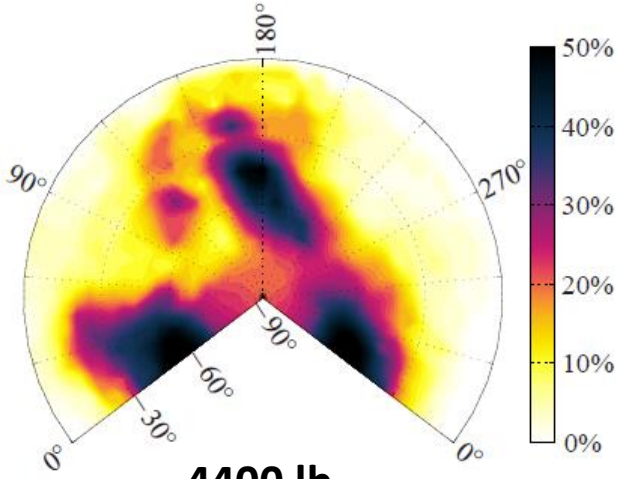

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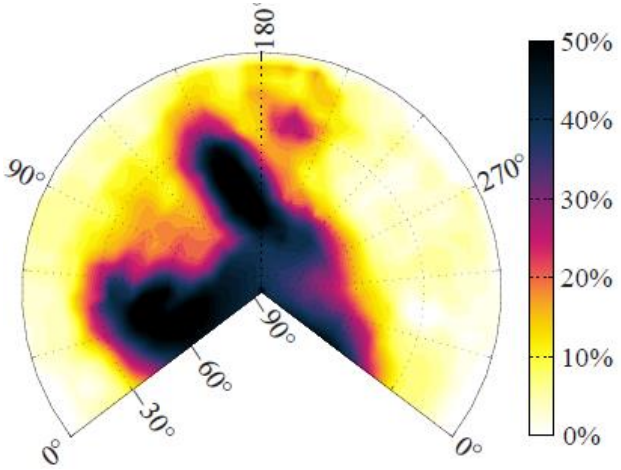

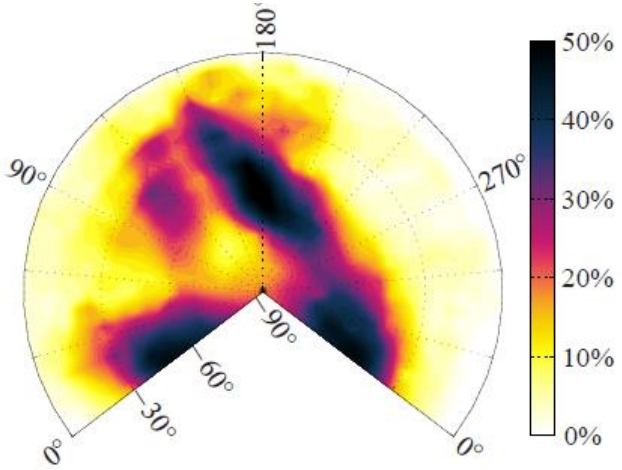

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